Elmer/Ice Beginner course 2023
CSC, Espoo, Finland

Introduction

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Thanks to …

- **CSC-IT Center for Science** for hosting the course

- **IGE**, **UGA** and **SNO-Elmer/Ice** at **CNRS** for supporting Olivier Gagliardini's travel and stay

- **UNIL**for supporting Samuel Cook's travel and stay

- **You** for being here
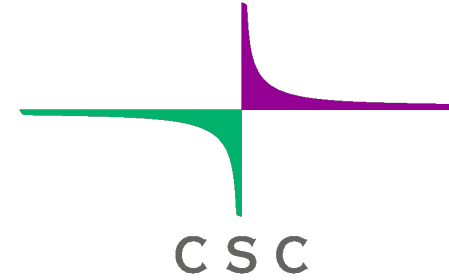
Program

Day 1, Nov. 13rd - Introduction + Synthetic Glacier

- **09:00** – 10:30 Welcome and introduction to Elmer/Ice + SIF crash course
- 10:30 – 11:00 Break
- 11:00 – 12:30 Synth Glacier Step 1
- 12:30 – 13:30 Lunch
- 13:30 – 14:30 Synth Glacier Step 2
- 14:30 – 15:00 Break
- 15:00 – **16:00** Synth Glacier Step 3

Day 2, Nov. 14th – Case Argentière

- **09:00** – 10:30 Diagnostic runs
- 10:30 – 11:00 Break
- 11:00 – 12:00 Ice age
- 12:00 – 13:00 Lunch
- 13:00 – 14:30 SMB and Prognostic
- 14:30 – 15:00 Break
- 15:00 – **16:00** Discussion and wrap-up

Elmer

elmer ICE

- **Elmer** (= multi-physics package) with additional routines for Glaciology

- Maintained and supported by **CSC**

- **Open Source** (GPL2 or later)
  - Transparence (you co-own the code)
  - Sustainability (no license fees)
  - Viral effect of GPL (new code also GPL)
  - Linking to library allowed under LGPL

- Large international user community
  - Knowhow of well-established institutions

- Good level of support/documentation
  http://elmerice.elmerfem.org

- Elmer/Ice builds on Elmer and includes developments related to glaciological problems. Elmer/Ice includes a variety of dedicated solvers and user functions for glaciological applications and their development is supported by various groups and funding…

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Elmer/Ice

- **Full-Stokes** (also SIA, SSA, Blatter-Pattyn) with post processing for stress/strain

- **Mesh:** Unstructured, vertically extruded, deforming and moving meshes

- **Temperature** solver accounting for pressure melting point or Enthalpy solver

- **Rheology:** Glen, anisotropy, firn densification, damage mechanics

- Special **sliding laws**: Weertman, Coulomb, Budd, Tsai

- Basal **hydrology** models (2): GlaDS and double continuum

- **NetCDF**-readers (for geometry as well as coupling to climate)

- Simple SMB (**PDD**)

- **Calving** models (3 approaches)

- **Inverse methods** for data assimilation

- Methods for **tracer transport/dating**

- Antarctica and Greenland configurations

- …

Elmer/Ice
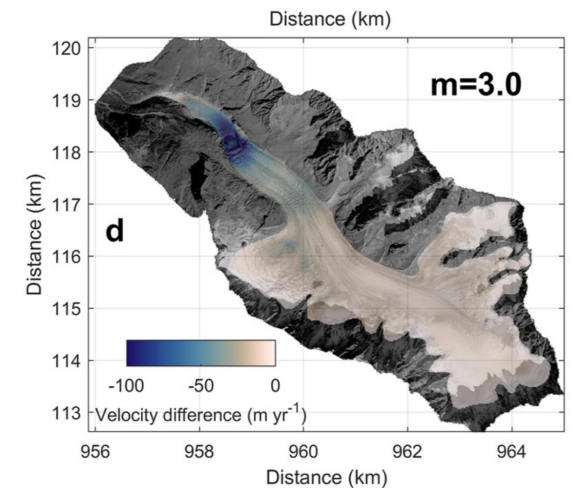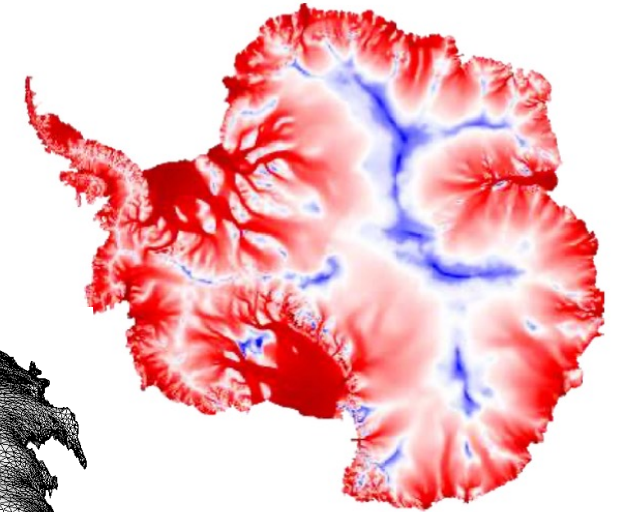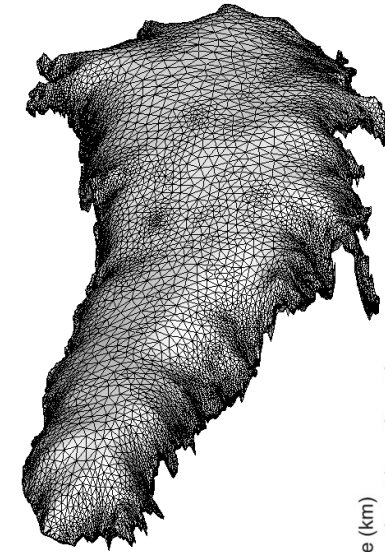
	Flow equations	Stokes	Blatter-Pattyn	SSA	SSA*	SIA	ISCAL
Rheology	Glen	X, Inv Adj + Rob	X	X, Inv Adj	X	X	X
	GOLF	X					
	CAFFE	X					
	POROUS	X					
	Damage	X	X	X	X	X	X
Basal friction	Linear	X, Inv Adj + Rob	X	X, Inv Adj	X		
	Weertman	X	X	X	X		
	Coulomb	X	X	X	X		
	Budd	X	X	X	X		
	Tsai		X	X	X		
Free surface	dS/dt	X	X	X	X	X	X
	dH/dt	X, Inv	X	X, Inv	X, Inv	X, Inv	X, Inv
Grounding line	Contact	X					
	Hydrostatic	X	X	X	X	X	
Calving	Fracture+Damage	2D					
	crevasse depth	X					
Temperature	Temperate	X	X	X	X	X	X
	Enthalpy	X	X	X	X	X	X
Hydrology	Two layers	X	X	X	X		
	GlaDS	X	X	X	X		
	Inv : Inverse methods, Adj (adjoint), Rob (Arthen & Gudmundsson, 2010)						

Elmer/Ice

- Finite element method (FEM)
  - Using linear elements and standard Galerkin with Stabilized Finite Elements or residual free bubbles

- Flow law → viscosity changes by order of magnitudes → bad conditioned system:
  - Direct parallel or tuned block-preconditioned iterative Solver

- (Large scale) parallel computing
  - MPI
  - OpenMP multi-threading and vectorization (SIMD)
 - Currently working towards GPUs (AMGX)

Fig. 4. Efficie[...]
nodes in all me[...]
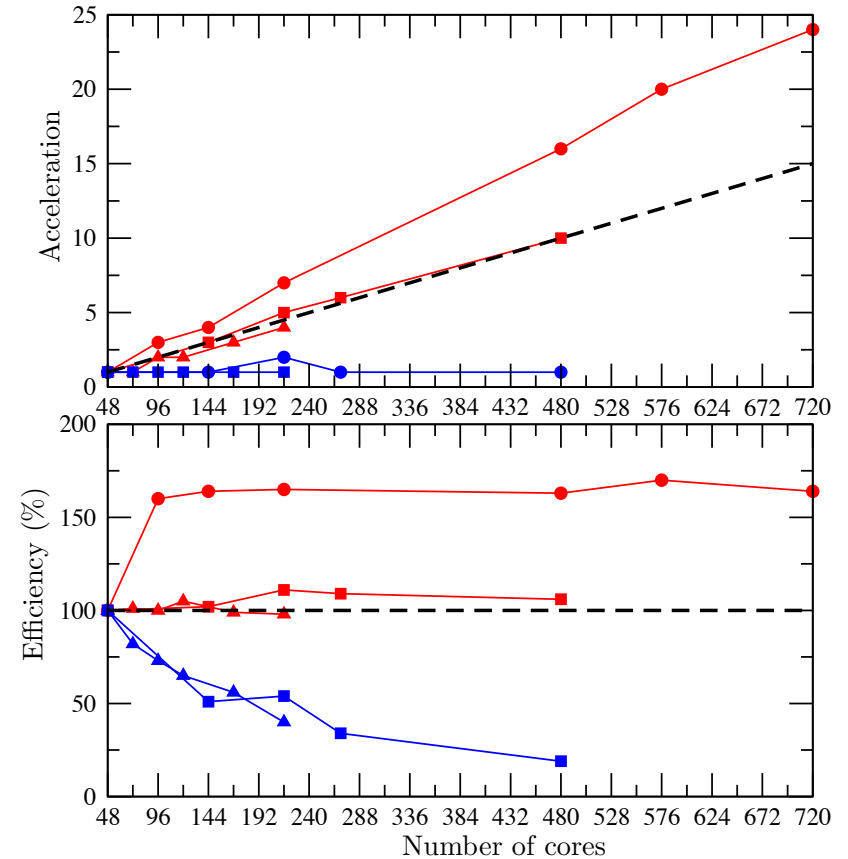
Gagliardini, O., T. Zwinger, F. Gillet-Chaulet, G. Durand, L. Favier, B. de Fleurian, R. Greve, M. Malinen, C. Martín, P. Råback, J. Ruokolainen, M. Sacchettini, M. Schäfer, H. Seddik, and J. Thies, 2013. *Capabilities and performance of Elmer/Ice, a new-generation ice sheet model*, Geosci. Model Dev., **6**, 1299-1318, doi:10.5194/gmd-6-1299-2013.

Elmer/Ice – coupling to other (Elmer) components

Calving - DEM (HiDEM)
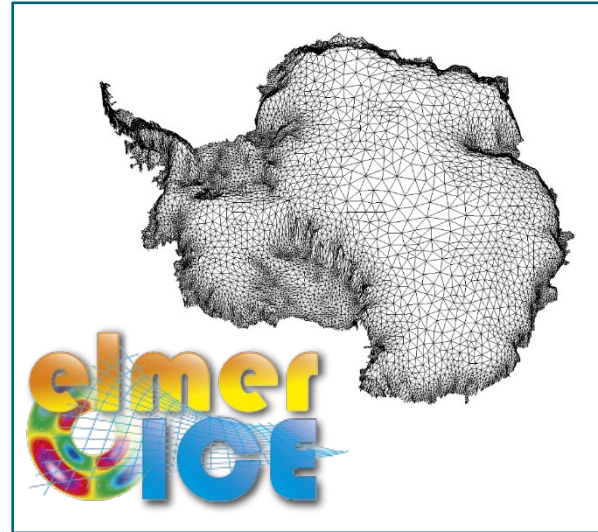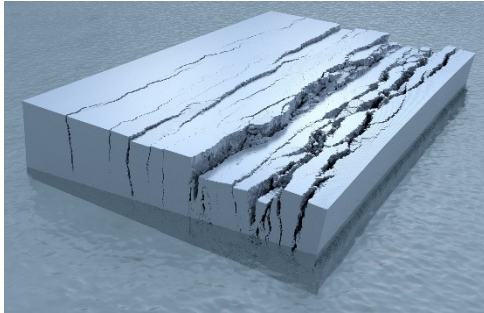
Ice-ocean coupler (FISOC)
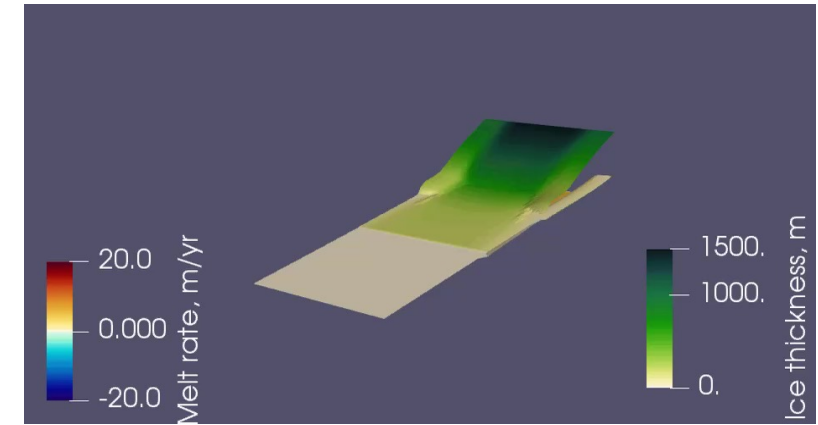
Glacial isostacy – VE model
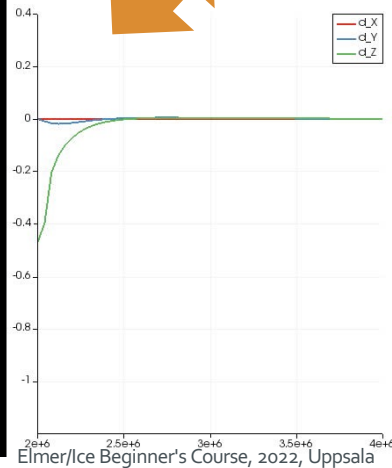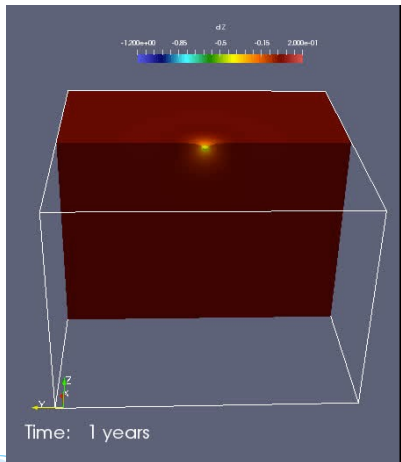
Groundwater and Permafrost model

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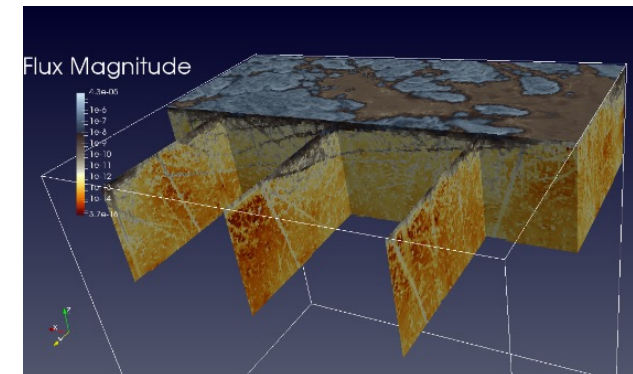
Elmer/Ice – short history & community activity (1/4)

- ✓ EGU2002: OG was looking for a 3D FE code to model the flow of strain-induced anisotropic polar ice – meet TZ

- ✓ March 2003: OG visited CSC for few days: AIFlowSolver and FabricSolver partly implemented

- ✓ August 2005 – One year visit of OG at CSC (Anisotropy, cavity, glaciers, ISMIP tests, …)

- ✓ **February 2008 – First Elmer/Ice Course – Grenoble**

- ✓ Elmer/Ice course at Beijing Normal University in March 2011

- ✓ June 2011 – SVALI summer school – Finland

- ✓ **2012 – Elmer/Ice has now a website, a logo and a mailing list**

- ✓ **2012 – Elmer/Ice comes as a Elmer Package – New wiki**

- ✓ 2012 – Elmer/Ice course at UBC/SFU

- ✓ 2013 – Elmer/Ice courses at Univ. Washington and Univ. Alberta

- ✓ **9 April 2013 – First Elmer/Ice users meeting – EGU 2013**

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Elmer/Ice – short history & community activity (2/4)

- ✓ May 2013 – Second SVALI summer school – Finland

- ✓ 2-day beginner Elmer/Ice course, 3-4 Oct. 2013, LGGE, Grenoble, France

- ✓ 3-day Elmer/Ice advanced workshop, 4-6 Nov. 2013, CSC, Espoo, Finland

- ✓ April 2014 – Second Elmer/Ice users meeting – EGU 2014

- ✓ 3-day beginner Elmer/Ice course, 27-29 Oct. 2014, IMO, Reykjavík, Iceland

- ✓ April 2015 – Third Elmer/Ice users meeting – EGU 2015

- ✓ 2-day beginner course, 1&2 Nov 2015, CIC, Copenhagen, Denmark

- ✓ 3-day Elmer/Ice advanced workshop, 30 Nov, 1&2 Dec 2015, LGGE, Grenoble, France

- ✓ 3-days beginner course, Oct 2016, Oslo

- ✓ April 2017 – Fourth Elmer/Ice users meeting – EGU 2017

- ✓ 2-day beginner Elmer/Ice course, 23rd and 24th Oct. 2017, University of Stockholm, Sweden

Elmer/Ice – short history & community activity (3/4)

- ✓ 3-day advanced Elmer/Ice workshop, 22nd, 23rd and 24th Nov. 2017, IGE, Grenoble, France

- ✓ 2-day beginner Elmer/Ice course, 22nd & 23rd Oct. 2018, University of Lapland, Rovaniemi, Finland

- ✓ 3-day Elmer/Ice advanced users workshop, 29th-31st Oct. 2018, CSC, Espoo, Finland

- ✓ April 2019 - Fifth Elmer/Ice Users Meeting - EGU 2019

- ✓ 2-day beginner Elmer/Ice course, 28&29 October 2019, University of Iceland, Iceland

- ✓ Sixth Elmer/Ice Users Meeting - Remotely May 2020

- ✓ Seventh Elmer/Ice Users Meeting - Remotely October 2020

- ✓ **Beginner Elmer/Ice Online course - 23-27 November 2020**

- ✓ 2-day beginner Elmer/Ice course, 8&9 October 2021, Univ. Oslo, Norway

- ✓ Eight Elmer/Ice User Meeting - Remotely February 2022

- ✓ **Creation of the Elmer/Ice Developer's Committee (DevComm) in June 2022**

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Elmer/Ice – short history & community activity (4/4)

✓ 2-day beginner Elmer/Ice course, 24&25 October 2022, Univ. Uppsala, Sweden

✓ 9th Elmer/Ice User Meeting - Remotely 7 December 2022

✓ 10th Elmer/Ice User Meeting - EGU, Vienna 2023

20 Courses ~ 400 participants → + this one in Finland!

10 Elmer/Ice users meetings → next one this Wednesday

Elmer/Ice - Community
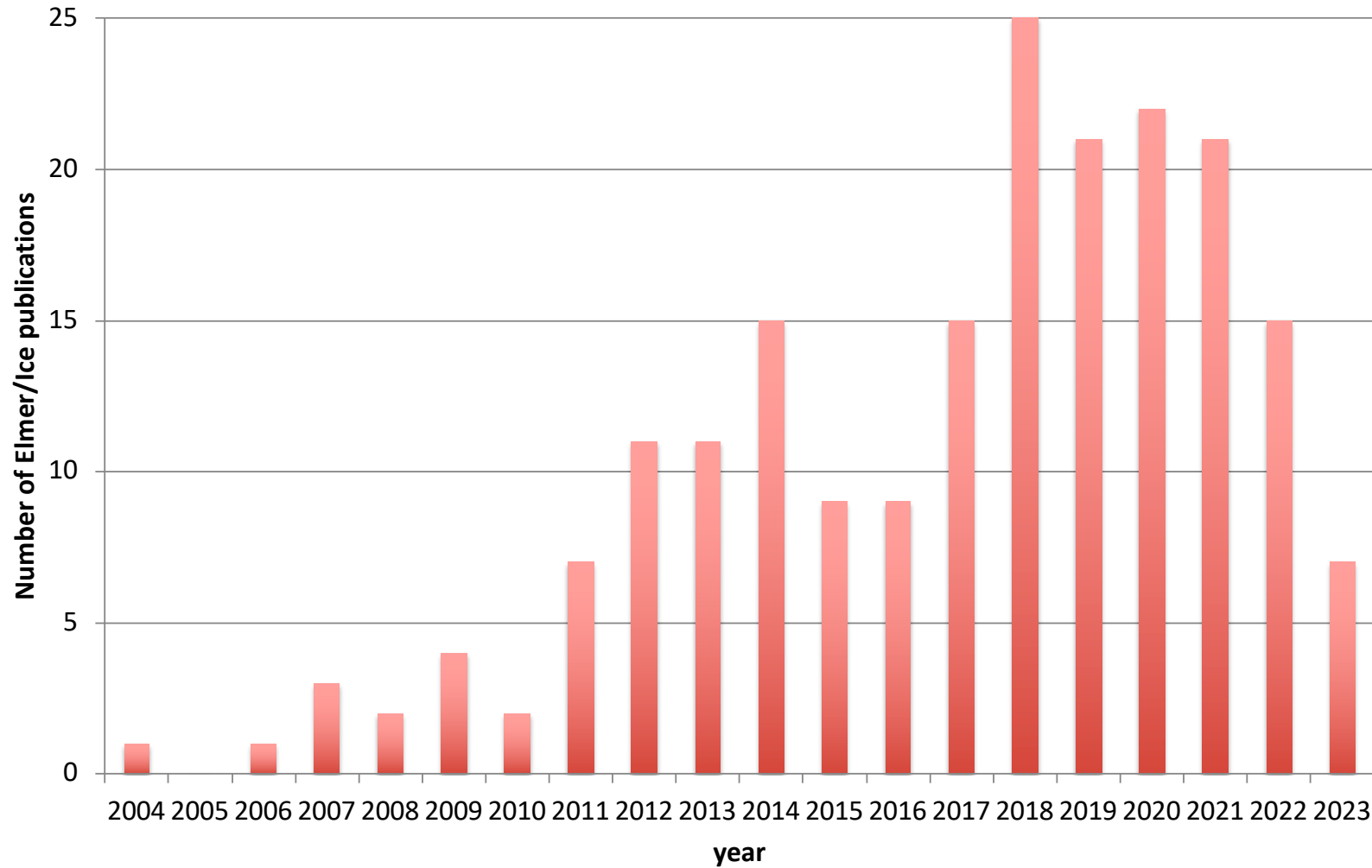
201 publications

Elmer/Ice - Community
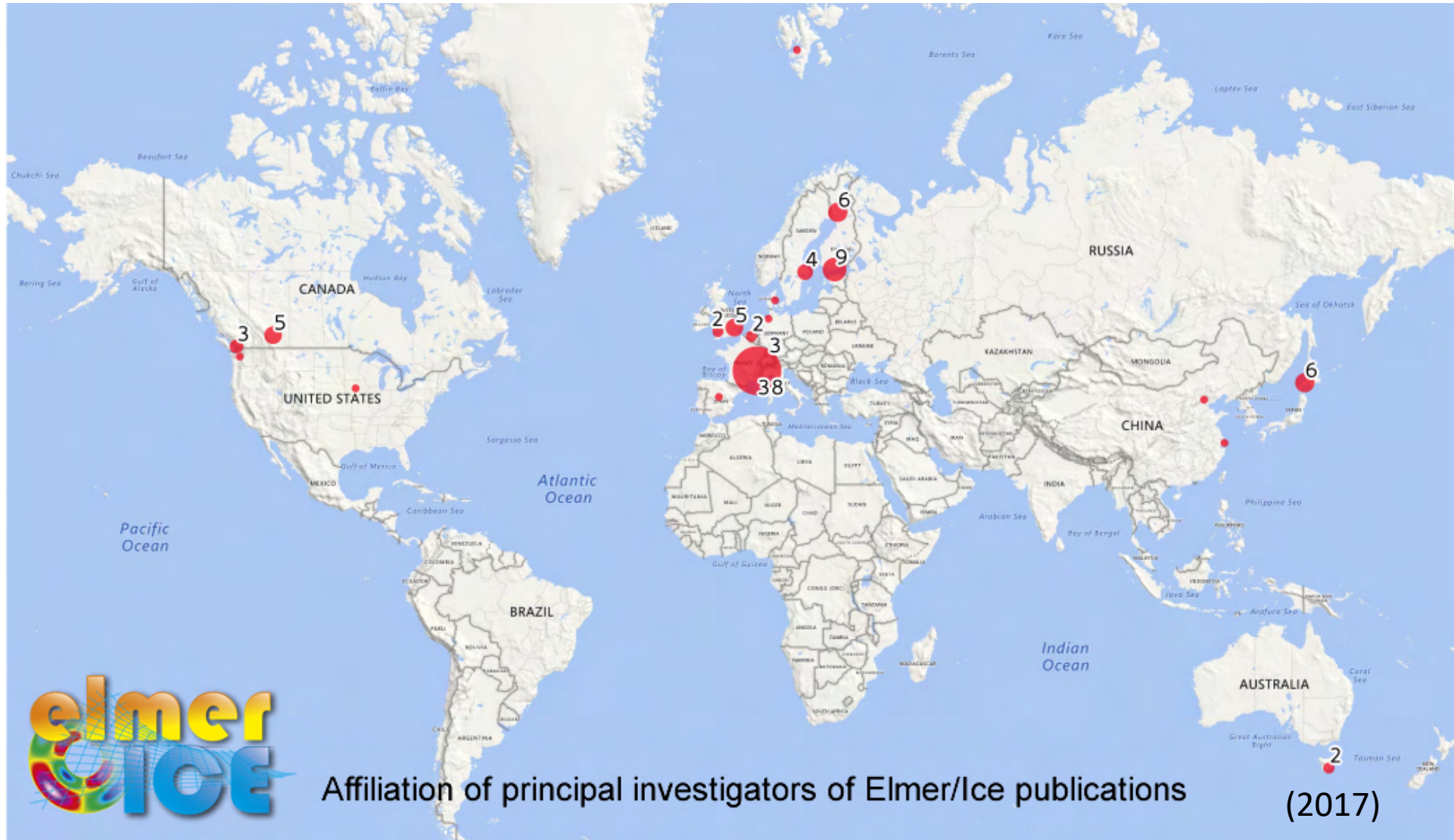
Affiliation of principal investigators of Elmer/Ice publications

(2017)

Elmer/Ice website

http://elmerice.elmerfem.org/

- **Community web-portal**:
  - Latest news
  - List of publications
  - Forum (see later)
  - Courses (indirect link to Wiki)
  - Direct link to Wiki

Elmer/Ice wiki

http://elmerfem.org/elmerice/wiki

- Contains documentation on Solvers, Userfunctions and also methods
  - We are porting documentation of sowftware to GitHub (see following slides)

- Contains also material of courses

Elmer source code

https://github.com/ElmerCSC/elmerfem

- Elmer/Ice specific files in subdirectory `elmerice`

- Elmer/Ice specific developments in branch **elmerice**
  - We merge frequently between the main branch (**devel**) and **elmerice**-branch

- Porting **documentation to GitHub**
  - `elmerice/Solvers/Documentation`
  - `elmerice/UserFunctions/Documentation`
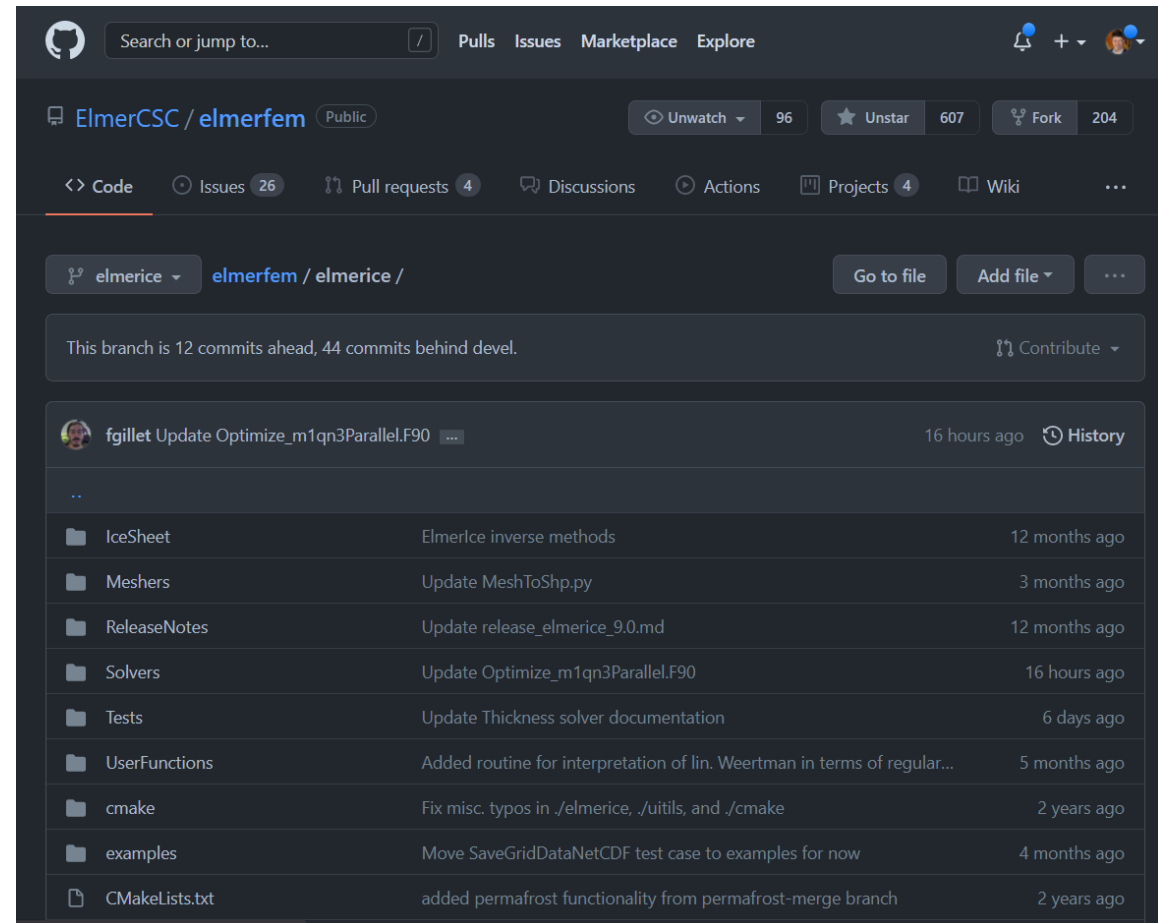
Elmer/Ice mailing list

Subscribe to the Elmer/Ice mailing list:

http://mail.elmerfem.org/mailman/listinfo/elmerice_elmerfem.org

Not a big flux, but important information (bug, new version, new publication, etc..)

Currently 85 members

Elmer/Ice Forum

Under http://www.elmerfem.org

- Go to **Elmer Forum:** find answers on all aspects of Elmer

- Click on **Elmer/Ice** link: find answers specific to Elmer/Ice

- To get access: **Register** in upper right corner

Elmer/Ice Slack space

o You should have received an invitation to join

o Can be used to ad-hoc communicate, particularly, in advance and during courses

o Is used by some members afterwards

o Main technical questions: please put them to the Forum, rather than in Slack! Thereby they can be looked up by a wider range of users.

Useful Links

- Elmer at CSC (documentation, how to install, ...)

http://www.elmerfem.org/

https://www.csc.fi/web/elmer

- Elmer (and thereby Elmer/Ice) source code

https://github.com/ElmerCSC/elmerfem

- Elmer Forum

http://elmerfem.org/forum/

- Elmer/Ice webpage

http://elmerice.elmerfem.org/

- Elmer/Ice wiki

http://elmerfem.org/elmerice/wiki/doku.php?id=start

About this course

- We will <u>not</u> teach finite element method (can give references)

- We will focus on some technical aspects of using Elmer for glaciological applications

- Expected outcome of this course :
  - giving you a kick-start with Elmer/Ice
  - some possible fruitful collaborations to begin

- **Conduct**:

https://github.com/ElmerCSC/elmerfem/blob/devel/CODE_OF_CONDUCT.md

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